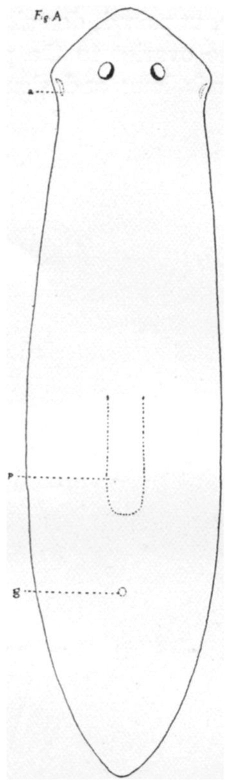
ON THE GERM CELLS AND THE EMBRYOLOGY OF PLANARIA SIMPLISSIMA.

BY N. M. STEVENS.

This planarian, which is found in small streams about Bryn Mawr, was identified provisionally in 1900 by Woodworth as *Planaria lugubris*, and has since figured under that name in several of Prof. T. H. Morgan's papers on regeneration; also in my "Notes on Regeneration in *Planaria lugubris*" (Stevens, '01).

On looking up the European species (*P. lugubris*) as described and figured by Schmidt ('59, Pl. III, figs. 5 and 6), and by Kennel ('79, Pl. VII, fig. 8), I felt sure that Woodworth must have been mistaken as to the species; but I was unable to find any correct description or figures, either of the external characters of the animal or of its reproductive organs, and I was inclined to call it a new species. In September, 1903, after this paper was written, I came across an article by Curtis ('00) on the reproductive organs of *Planaria simplissima* n. sp. The reproductive organs of this species were so strikingly like those of the form on which I had been working that, although there was considerable difference in form, size and color, I was convinced that the two worms must be closely related, if not local varieties of the same species.

In answer to my inquiries about *Planaria simplissima*, Prof. Curtis has recently written me that after studying specimens sent to him by Prof. Morgan from Bryn Mawr, and sectioning others of the same species found near Baltimore in 1900 and 1901, he concluded that the Williamstown form, *P. simplissima* (fig. B), and the Bryn Mawr form *P.* (*lugubris*), (fig. A) belonged to the same species. Prof. Curtis desires me to state that his description of the external characters of *P. simplissima* was made from fixed material, living specimens not being accessible when he discovered that he was dealing with a new species. Later observations on living specimens from Williamstown made it apparent that his description was at fault, especially with regard to the lateral cephalic appendages which are more marked than was evident in fixed material. A careful sketch, made at this time from the living animal and sent to me with his letter, is a good representation of a young specimen of the Bryn Mawr form (figs. A and B)



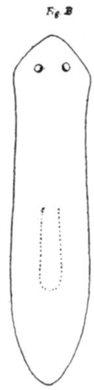


Fig. A. Outline sketch of a large mature specimen of *Planaria simplissima*. *a*=gray sensory area on the lateral auricular appendage. *p*=pharynx. *g*=genital opening.

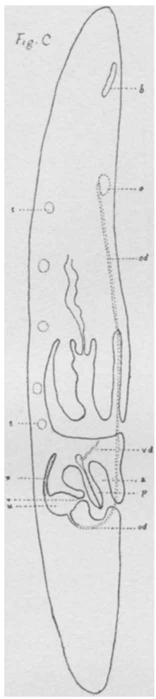
Fig. B. Outline drawing from Curtis's sketch of a small specimen from Williamstown.

and, I think, leaves no doubt that we have the same species, which may be described as follows:

Planaria simplissima Curtis.

Length of mature specimens 7–15 mm.; breadth 2–4 mm. Color a nearly uniform seal-brown (occasionally grayish) with an inconspicuous gray area on each cephalic appendage. Eyes gray with a crescent of black pigment on the median side. Both anterior and posterior ends blunt. Lateral cephalic appendages blunt and inconspicuous as compared with *P. maculata*. Body thick as compared with *P. maculata*. Pharynx just posterior to the middle point of the longitudinal axis of the worm. Ovaries two, ventral, somewhat lobed, and situated about half-way from the anterior end of the animal to the pharynx.

Testes four or five on each side, unpaired, dorsal, and irregularly distributed from the region of the ovaries to the posterior end of the pharynx (figs. C and D). Penis long and slender, not filling the



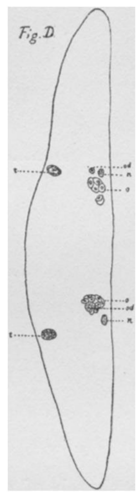


Fig. C. Median longitudinal section of *Planaria simplissima* showing reproductive organs. Parts out of the plane of the section are shown in dotted lines. *a*=antrum. *b*=brain. *o*=ovary. *od*=oviduct. *p*=penis. *t*=testis. *u*=uterus. *vd*=vas deferens of one side. *x*=ciliated tube opening into uterus. *v*=vagina.

Fig. D. Reconstruction from several cross-sections showing ovaries (*o*), oviducts (*od*), nerve cords (*n*) and testes (*t*).

antrum. Uterus consisting of a chamber lined with glandular epithelium, dorsal to the antrum, and with an anterior prolongation in the form of a narrow ciliated tube with no enlargement at its anterior end. Vasa deferentia two, opening separately into the anterior enlargement of the lumen of the penis. Oviducts two, ventral and parallel with the nerve-cords, uniting before entering the uterus (figs. C and D). Vitellaria extending from the region of the ovaries to the posterior extremity of the animal.

Found on the under side of stones and leaves along the margin of small streams.

The original object of this paper was a discussion of the reproductive organs, ovogenesis, spermatogenesis and embryological development of *Planaria* (*lugubris*). The discovery that it is not *P. lugubris* but *P. simplissima* Curtis renders further discussion of the reproductive organs unnecessary, and I shall therefore confine my attention to a study of the germ-cells and the embryology of this species, which presents some peculiarities not fully described by Ijima ('84) and Hallez ('79).

Fertilization.—Copulation has not been observed in this species, but there is every reason for supposing that it occurs, for spermatozoa are found only in the vasa deferentia, the lumen of the penis, the uterus and the oviduct. In nearly every specimen the anterior end of the oviduct is crowded with spermatozoa (Pl. XIII, fig. 1, *od*), while only occasionally one is found in the posterior part of the duct or in the uterus. The spermatozoa are never found among the oöcytes in the ovary, and it is probable that each egg is fertilized as it enters the oviduct, for the spermatozoon is always found in the eggs of a forming capsule, and no spermatozoa are found among the eggs and yolk.

I should therefore agree with Ijima in regarding the uterus as a gland for forming the cocoon shell, and not as the place where fertilization occurs (Hallez), or as a receptaculum seminis (Kennel).

Fig. E.

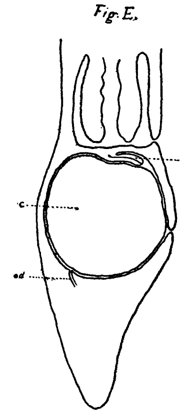


Fig. E. Median longitudinal section through an individual containing an egg-capsule (*c*). *od*= oviduct. *p*= penis

When an egg-capsule is forming, the antrum, uterus and the tube *x* (fig. C) are all thrown into one chamber, which is filled with eggs and yolk-cells, the penis being pushed back against the anterior wall of the antrum (fig. E) and the antrum being separated from the pharynx-chamber by so thin a layer of tissue that it is often broken through in fixed specimens, and yolk-cells are found in the pharynx-chamber.

Ovogenesis.—The early stages in the development of the oöcytes evidently should be studied in the summer after laying-time, for the ovaries are practically unchanged in appearance from October to laying-time in April. Figure 1, drawn from a section cut in November, shows nearly all of the oöcytes in the same condition as in sections containing the first maturation-spindle (cut in April and May). The cytoplasm of the oöcytes stains deeply with hæmatoxylin and

contains here and there a yolk-granule in a vacuole (fig. 2*a*, *y*). The nucleus is very large and shows but little stainable chromatin, and that in the form of fine granules on threads of linin. The large nucleolus, which stains deeply with orange, contains one or more vacuoles. As in my previous work on the histology of planarians (Stevens, '02), the best results were obtained by fixing the material with sublimate-acetic and staining with Delafield's hæmatoxylin and orange.

The first maturation-spindle is found in the ovary about twenty-four hours before laying. In an equatorial stage the spindle is near the centre of the egg. The asters are very large, but there is no evidence of centrosome or sphere. The chromosomes are V-shaped, and split longitudinally, giving V-shaped daughter chromosomes, as in figs. 3*a* and 3*b*. Only four specimens in this stage were obtained out of a large number sectioned; and of these, three had either 3 chromosomes in an equatorial plate (figs. 2*a* and 2*b*) or 6 daughter chromosomes (figs. 3*a* and 3*b*), and one had 4 in the equatorial plate (fig. 4). Time and material were lacking to trace the egg from the ovary to the uterus, after it was ascertained that an interval of about twenty-four hours occurred between the formation of the first and second polar bodies.

By removing the capsule before the shell is formed and staining with Schneider's aceto-carmine, the second maturation-division can be more advantageously studied than in sections. Figs. 8–11 were made from such preparations; figs. 5*a*, 5*b* and 6, from sections. In only two cases was the first polar body observed (figs. 6 and 8), and it seems probable that it is usually lost as the egg passes down the oviduct. The number of egg-chromosomes is 3 in most cases. In two eggs from the same capsule the number was 6 (figs. 9 and 10), and in a few others 4 and 5 were observed, indicating that, as in *Ascaris megalocephala* and *Echinus microtuberculatus,* there may be two forms which occasionally interbreed, one having twice as many chromosomes as the other.

Thus an egg having 6 chromosomes fertilized by a spermatozoon having 3 would give an individual having 9 somatic chromosomes and probably 5 chromosomes in germ-cells after reduction. Union of germ-cells having 3 and 5 chromosomes respectively would result in an individual having 8 chromosomes in somatic cells, and 4 in oöcytes and spermatozoa.

Figure 8 shows an egg in which there was no doubt about the number 3 in the first polar body (p^1), and at the poles of the second maturation-

spindle (p^2 and e). Figure 7 is a somatic cell containing 6 chromosomes. Six have also been counted several times in the first segmentation-division. That the second maturation-division of the chromosomes is longitudinal like the first one is evident from the form of the chromosomes and from the pairs seen at a and b in fig. 10. Figure 11 shows the second polar body separating from the egg.

Spermatogenesis.—As in the case of the ovaries, the testes should be studied in summer after laying-time, in order to follow the development of the spermatogonia, but occasional divisions of spermatogonia and both spermatocyte-divisions may be observed in material preserved at any time during the autumn and winter. My best material was fixed about the first of December. Pl. XV, fig. 15, shows a part of the section of a testis which contained dividing spermatogonia (a), both maturation-divisions (e and f), spermatids in all stages (g, h, i, k, l), and ripe spermatozoa. In this animal the number of chromosomes in the maturation-divisions was 4, in the spermatogonia 8. In several others only 3 were found in the spermatocytes (figs. 20 and 22). Various phases of the first maturation-division are shown in figs. 16–21 and of the second in figs. 22 and 23. The form of the chromosomes in all phases of both divisions is the same, a Y-shape, easily distinguishable from the V-shaped and U-shaped chromosomes of the spermatogonia and somatic cells. There is no evidence of a transverse, or reducing, division. In an anaphase (figs. 20 and 22), each daughter chromosome appears to be drawn toward the pole of the spindle by a single fiber attached to the stem of the Y. The spindle is composed of very few fibers, and neither centrosomes nor asters have been demonstrated. The spermatocytes before division appear as in fig. 15, d, and nothing corresponding to the synapsis stage described by various authors has been found. The spermatogonia in both resting and division-stages closely resemble the so-called embryonic or parenchyma cells which are scattered through the planarian body and play a conspicuous rôle in regeneration (fig. 15, a).

Figs. 24–32 show various stages in the development of the spermatozoön. The nucleus of the spermatid contracts, forming a small ball of nuclear material which stains deeply and uniformly (figs. 24–27, a). This concentrated nucleus gradually elongates (figs. 27, b–29), and finally leaves the cytoplasm tail first (figs. 15 and 29). Many empty spermatid cells are shown in fig. 15, n. The spermatozoön appears to be formed wholly from the nucleus of the spermatid, and stains like chromatin throughout. The spermatozoa in the oviduct near the ovary have a knob-like appendage near the anterior end (fig. 32)

This appears to be a late development, as it is not found on the spermatozoön in the testes, vasa deferentia, or lumen of the penis.

Embryological Development.—As stated above, the first maturation-division of the egg occurs in the ovary; fertilization probably takes place in the oviduct; and the second maturation-division is found in the forming capsules. The eggs of capsules just laid always show the two pronuclei with very large nucleoli, as in Pl. XIII, fig. 12, and a few hours later the pronuclei are fused as in fig. 13, but the two nucleoli are distinct. The development of the eggs during the first day can be best studied in aceto-carmine. Sections of these and of older capsules may be obtained by piercing the shell with a needle and fixing in sublimate-acetic. The shell must be removed before embedding. The rate of development varies greatly in different capsules, and even among the eggs of the same capsule. Laying occurs in the morning from daylight to ten o'clock. In one case the first cleavage-spindle was found at 10.30 A.M. in one egg of a capsule, in which all the others showed the pronuclei not fused. In other capsules eggs containing the pronuclei were found as late as 5 P.M. Two, four and eight-celled stages were also occasionally found late in the afternoon. Figure 14, *a*, was from an egg stained with aceto-carmine at 4.30 P.M. There were 6 chromosomes at each pole, as shown in fig. 14, *b*, obtained by focussing down on one end of the spindle. As in the maturation-divisions, neither centrosome nor sphere could be demonstrated.

The peculiar positions taken by the blastomeres in 2, 4 and 8-celled stages is shown in Pl. XIII, figs. 33–36. Fig. 35 is a reconstruction from five successive sections. Fig. 36 is a section of a 32-celled stage in which the yolk-cells near the group of blastomeres have begun to break down in the region *x*............*x*. The next stage (Pl. XV, fig. 37) shows a section of an embryo, consisting of a syncitial yolk-mass (y^1), distinct from the surrounding yolk-cells and disintegrated yolk-material. The group of blastomeres is always irregular in orm and eccentrically situated, coming to the surface on one side of the yolk-mass. Some of the blastomeres soon begin to wander through the syncitium, and may be found dividing at any point. A section of a capsule at this stage frequently shows sections of three or four such embryos. The embryonic yolk-mass gradually increases in size, as may be seen by comparing figs. 37–40, all drawn with the same magnification. The embryo is partly or wholly surrounded by a region of disintegrated yolk-cells (fig. 37, *a*), from which material for the embryonic syncitium is evidently drawn. In some cases whole yolk-cells appear to be taken into the syncitium in amœboid fashion.

In fig. 38, p^1, the first cells of the embryonic pharynx are distinguished from the surrounding blastomeres by their different staining qualities. Figs. 39–41 show the characteristic structure of such a pharynx which is well developed, but not yet functional. Fig. 40 is a median vertical-section through the pharynx, fig. 39 a median cross-section through the central cells (b), and fig. 41 a cross-section through the four inner cells (d). The cells which surround the lumen of the pharynx are twelve in number—four somewhat flattened surface cells (a), four cylindrical central cells (b), and four nearly spherical inner cells (d). Metschnikoff ('83) suggests that the latter group of four cells, supposed by some to represent the primary endoderm, may serve as a valve to prevent the escape of yolk-cells. The central cells are surrounded by a considerable number of smaller cells radially arranged and supposed to be muscle-cells serving to open the pharynx. Figs. 39 and 40 also show wandering blastomeres in all parts of the syncitial yolk-material of the embryo. A few of these are flattened to form a partial epithelium. Fig. 42 is a section through a functional pharynx taking in yolk-cells (y^2). The central cells (b) are much flattened to form the lining of the lumen, and the muscle-cells are lengthened radially. The two inner cells shown in dotted outline belong to the next section.

Up to the time when the embryonic pharynx becomes functional, the embryo is a solid ball of yolk in the form of a syncitium containing scattered blastomeres, with the developing pharynx at one side, in the region where segmentation began. Here and there over the surface are flattened blastomeres forming an incomplete epithelium (figs. 39–40). As the yolk is sucked in, the embryo becomes a hollow ball filled with yolk-cells (figs. 43–47). [In these and the following figures the space occupied by the yolk cells sucked in by the embryonic pharynx—the secondary yolk (y^2)—is not filled in.] Fig. 43 is a section of a nearly spherical embryo from a capsule in which some yolk still remained around the embryos. Fig. 44 is a cross-section of a flattened embryo of full size, all the yolk outside of the embryos having disappeared. In these sections the blastomeres (b) are scattered in the primary yolk-material (y^1) of the embryonic surface layer of the embryo, and still possess the characteristics of the earlier blastomeres, deeply-staining cytoplasm and large nucleus containing a conspicuous nucleolus. Figs. 45 and 46 show parts of sections from somewhat older embryos, where the embryonic pharynx (p^1) is degenerating and the blastomeres have multiplied so as to nearly fill the embryonic layer, very little yolk remaining among them. The embryonic pharynx

disappears completely before the adult pharynx begins to form, but its relation to that pharynx appears to be the same as in *P. maculata*, as recently described by Curtis ('02). In fig. 45 the ventral side of the embryonic layer is easily distinguishable from the dorsal side by its greater thickness, and the degenerating pharynx (p^1) is on the dorsal side, as in Curtis's fig. 51, Pl. 17. The embryonic pharynx disappears so early, when many of the embryos are quite irregular in form, that it is impossible to tell whether it has a fixed position relative to the permanent pharynx or not, but my impression is that its position is variable. There is no evidence whatever that the embryonic pharynx serves as a tube leading to the anlage of the permanent pharynx, as described by Metschnikoff ('83) for *Planaria polychroa.*

Fig. 47 is from a 4-day embryo in which the pharynx-chamber appears as a split in the thickened ventral region of the embryo. In this stage pigment and rhabdites have begun to appear in the surface epithelium-cells, and rhabdite-cells are found among the embryonic cells, which are no longer like the early blastomeres, but closely resemble the embryonic cells of newly regenerated regions of adult planarians. Figs. 48 and 49 are sections of an older embryo (5–6 days), showing the permanent ectoderm well developed and full of pigment and rhabdite-cells. So far as I am able to determine, the ectoderm is formed from the outer embryonic cells and not by division of the earlier scattered epithelium-cells. There is considerable evidence that rhabdite-cells migrate from the interior to the surface and become a part of the ectoderm. In this embryo (figs. 48–51) the pharynx (p^2) is quite large and has a lumen connected with the central yolk-area (fig. 50). The yolk-area is being gradually divided up by strands of cells extending inward from the surface layer of embryonic cells to form the boundaries of the axial gut and its principal branches. Fig. 52 is from an older embryo (7 or 8 days), in which the development of the digestive tract is quite far advanced. In fig. 49 there is a section of a very young eye (*e*), the pigmented cup consisting of only 5 or 6 cells. No brain is yet distinguishable, but the lateral nerve-cords are represented by a few strands of nerve-fibers (*n*). In fig. 52 the eye is much further advanced and the nerve-cords are larger. The eyes in all embryos of this age are situated much deeper in the tissue than in the adult. There is as yet no definite endoderm, but here and there are cells with nuclei like those of adult endoderm-cells, and processes extend out from them among the yolk-cells as seen in fig. 51, *e*.

Fig. 53 is a cross-section of an embryo just before hatching (12th day). The lumen of the digestive tract is still full of yolk-cells and

the endoderm-cells also contain masses of yolk (y^2). Figs. 55 and 56, endoderm-cells containing large masses of yolk, were taken from the same embryo as Fig. 53. Fig. 57 shows a similar endoderm-cell from a young planarian one day old. This cell contains one of the large vacuoles (v) characteristic of adult endoderm-cells, and the yolk is much disintegrated.

Thus it is perfectly plain, in this form at least, that the yolk-cells do not serve as a "vicarious endoderm" (Metschnikoff); but endoderm-cells, developed from the embryonic cells of the one germ layer, consume the yolk-cells in the same manner as they do other food material later on.

Fig. 54 is a section from the head region of the same embryo as fig. 53, showing brain (b) and eyes (e). By the fourth day after birth the yolk has all disappeared from the lumen of the gut, but masses of it are still to be seen in the endoderm-cells. The late embryos and young planarians contain a very large proportion of embryonic cells and few muscle- and gland-cells compared with mature animals. The tissue of the whole body resembles that of recently regenerated parts of adult planarians. It is interesting to note that the interval between egg-laying and the development of the permanent pharynx, eyes and nervous system in the embryo is about the same as between merotomy and regeneration of the same organs in pieces of adult planarians.

The reproductive organs develop late, and as yet have been studied in only two specimens. In one young planarian, 8 weeks old, one ovary was found, but no other reproductive or genital organs. In another, 10 weeks old, there was a small antrum with the penis just forming, but no genital pore; one ovary and three testes were found. The oöcytes in these young ovaries were small and only just distinguishable from the cells of the yoke glands, which were quite well developed. In the testes there were already mature spermatozoa.

Summary.

The points that seem to need especial emphasis are:

1. In *Planaria simplissima* division of the chromosomes in both maturation-divisions is longitudinl.

2. The number of chromosomes in the maturation-divisions of the germ-cells varies frrom 3 to 6, but is usually 3.

3. In the embryological development there is nothing corresponding to the typical blastula and gastrula. After several segmentation divisions the blastomeres form an irregular group embedded in a syncitial yolk-mass which forms a part of the embryo. Some of the blasto-

meres form the embryonic pharynx; others wander through the syncitium.

4. The embryonic layer which covers the secondary yolk (y^2) taken in by the embryonic pharynx, in no way corresponds to the ordinary gastrula-stage. The solid embryo has, by sucking in yolk through its pharynx, become a hollow ball filled with secondary yoke-cells (y^2). The embryo now consists of a single layer of syncitial yolk-material, containing scattered blastomeres which feed on the primary yolk-material and multiply until they occupy the whole space previously filled by the primary yolk (figs. 43–46). Then the inner embryonic cells begin to serve as endoderm-cells to absorb the secondary yolk.

5. The axial gut and its principal branches are formed by ingrowths from the embryonic layer, dividing up the central space which is filled with secondary yolk (y^2).

6. Ectoderm, endoderm, permanent pharynx, eyes, nervous system, reproductive organs, gland- and muscle-cells are all formed by direct differentiation of the embryonic cells of the *one* embryonic or germ-layer. There is no formation of two or three distinct germ layers, nor are any of the organs formed by folding as in most other forms.

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Description of Plates XIII, XIV, XV and XVI.

Plate XIII, Fig. 1.—Ovary showing large oöcytes and oviduct full of spermatozoa (*od*). Bausch and Lamb, obj. $\frac{1}{2}$ in., oc. C, camera.

Fig. 2, *a* and *b*.—Ovarian egg showing first maturation-spindle with 3 chromosomes. y = yolk granule. B. and L. $\frac{1}{5}$–C.

Fig. 3, *a* and *b*.—Same as above with 6 daughter chromosomes.

Fig. 4.—Same with 4 chromosomes (a part of one chromosome in next section).

Fig. 5, *a* and *b*.—Egg from section of a capsule before laying, showing second maturation-spindle and 3 chromosomes. s = sperm.

Fig. 6.—Same as above, showing first polar body and 3 chromosomes.

Fig. 7.—Somatic cell from a regenerating piece of *Planaria lugubris*, showing 6 chromosomes. B. and L. $\frac{1}{12}$–C.

Fig. 8. Egg from a capsule before laying, stained with Schneider's aceto-carmine. p^1 = 1st polar body. p^2 = chromosomes of 2d polar body. s = sperm. e = egg-chromosomes. B. and L. $\frac{1}{5}$–C.

Fig. 9.—Similar egg with 6 egg-chromosomes (e) and 6 chromosomes for the 2d polar body (p^2).

Fig. 10.—Egg from same capsule as 9, showing longitudinal division at a and b.

Fig. 11.—Similar egg showing 2d polar body (p^2), sperm (s) and egg-chromosomes (e).

Fig. 12.—Egg from capsule just laid showing pronuclei.

Fig. 13.—Egg from capsule 3–4 hours after laying, showing pronuclei fused but nucleoli distinct.

Fig. 14*a*.—Egg from a capsule 8–10 hours after laying, showing first segmentation-spindle with 6 chromosomes at each pole.

Fig. 14*b*.—Optical cross-section of polar plate, showing two cross-sections of each of the 6 chromosomes.

Figs. 33–35.—2-celled, 4-celled and 8-celled stages from sections of capsules, showing the peculiar relative positions of the blastomeres. Fig. 35 is a reconstruction from five sections. B. and L. $\frac{1}{5}$–C.

Fig. 36.—Section of a 32(?)-celled stage, yolk-cells breaking down at x, x. B. and L. $\frac{1}{2}$–C.

Plate XIV, Fig. 15.—One-half of a cross-section of an unusually large testis. a = dividing spermatogonium. b = small spermatagonium after division. c = resting spermatgonium. d = resting spermatocyte of the first order. e = first maturation division. f = second maturation division. g = young spermatids. h, i, k = spermatids in later stages. l = spermatid apparently twice the usual size. m = spermatozoa. n = empty spermatid cells. B. and L. $\frac{1}{5}$–C.

Figs. 16–21.—Various phases of first maturation divisions, showing 3 and 4 chromosomes. B. and L. $\frac{1}{12}$–C.

Figs. 22 and 23.—Second maturation division.

Figs. 24–29.—Spermatids in various stages.

Figs. 30–31.—Spermatozoa from the testis.

Fig. 32.—Spermatozoon from the oviduct near the ovary. B. and L. $\frac{1}{12}$–C.

Plate XV, Fig. 37.—Section of a slightly later stage (64-celled)(?), showing an irregular mass of blastomeres (b), a definite embryonic yolk-area (y^1) and a region of disintegrating yolk-cells (a). B. and L. $\frac{1}{2}$–C.

Fig. 38.—Section of a still later stage, showing larger embryonic area containing yolk-nuclei (y^1), yolk-cells (y^2), wandering blastomeres (b), and the beginning of the embryonic pharynx (p^1). Same magnif.

Fig. 39.—Cross-section through the central cells (b) of an embryonic pharynx (p^1), well-developed, but not yet functional. c = muscle-cells. y^1 = yolk-nucleus. $bl.$ = blastomeres scattered in the yolk of the embryonic area. e = flattened blastomere on the surface of embryo.

Fig. 40.—Longitudinal-section through an embryonic pharynx of the same age as 39. a = two of the 4 large surface cells bounding the lumen. b = two of 4 central cells. c = muscle-cells. d = two of the 4 inner lumen-cells. e = a blastomere partly on the surface of the embryo. y^1 = yolk-nucleus. B. and L. $\frac{1}{2}$–C.

Fig. 41.—Cross-section of the 4 inner lumen-cells of the embryo shown in Fig. 39.

Fig. 42.—Functional pharynx, lumen open and yolk-cells entering. Same magnif.

Fig. 43—Section of embryo which has sucked in a large amount of yolk (y^2) but is still surrounded by yolk. p^1 = functional pharynx closed. b = a blastomere in embryonic layer. y^1 = yolk-nucleus of embryonic layer. B. and L. 1–C.

Fig. 44.—Section of embryo from a capsule where all the yolk has been absorbed, embryo somewhat flattened. y^2 = yolk taken in by pharynx.

Fig. 45.—Part of a section of an older embryo showing blastomeres filling the embryonic layer, slightly thicker ventral side, and degenerating embryonic pharynx (p^1).

Fig. 46.—Small part of section from same embryo showing dividing blastomeres or embryonic cells, very little yolk and few yolk-nuclei (y^1) among the embryonic cells. B. and L. $\frac{1}{5}$–C.

Fig. 47.—Later embryo (4th day) showing a very early stage in the formation of the permanent pharynx (p^2). e = ectoderm-cell containing pigment and rhabdites. r = rhabdite-cell. B. and L. 1–C.

Fig. 48.—Sections from an older embryo (6th day) showing later stage of the pharynx (p^2), well-developed ectoderm, and stands of embryonic cells beginning to divide off the central yolk-region into axial gut and its branches. a = endoderm-cells beginning to take in yolk-cells. e = very young eye, optic cup of about 5 pigmented cells. n = first appearance of nerve-cord.

Plate XVI, Fig. 49.—The same as fig. 48.

Fig. 50.—Another section of pharynx (p^2) from same embryo.

Fig. 51.—Section from same embryo, showing endoderm-cells (e) sending out processes among the yolk-cells (y^2). B. and L. $\frac{1}{5}$–C.

Fig. 52.—Section from an older embryo (7–8 days) showing older eye (e), larger nerve-cord (n) and formation of gut more advanced.

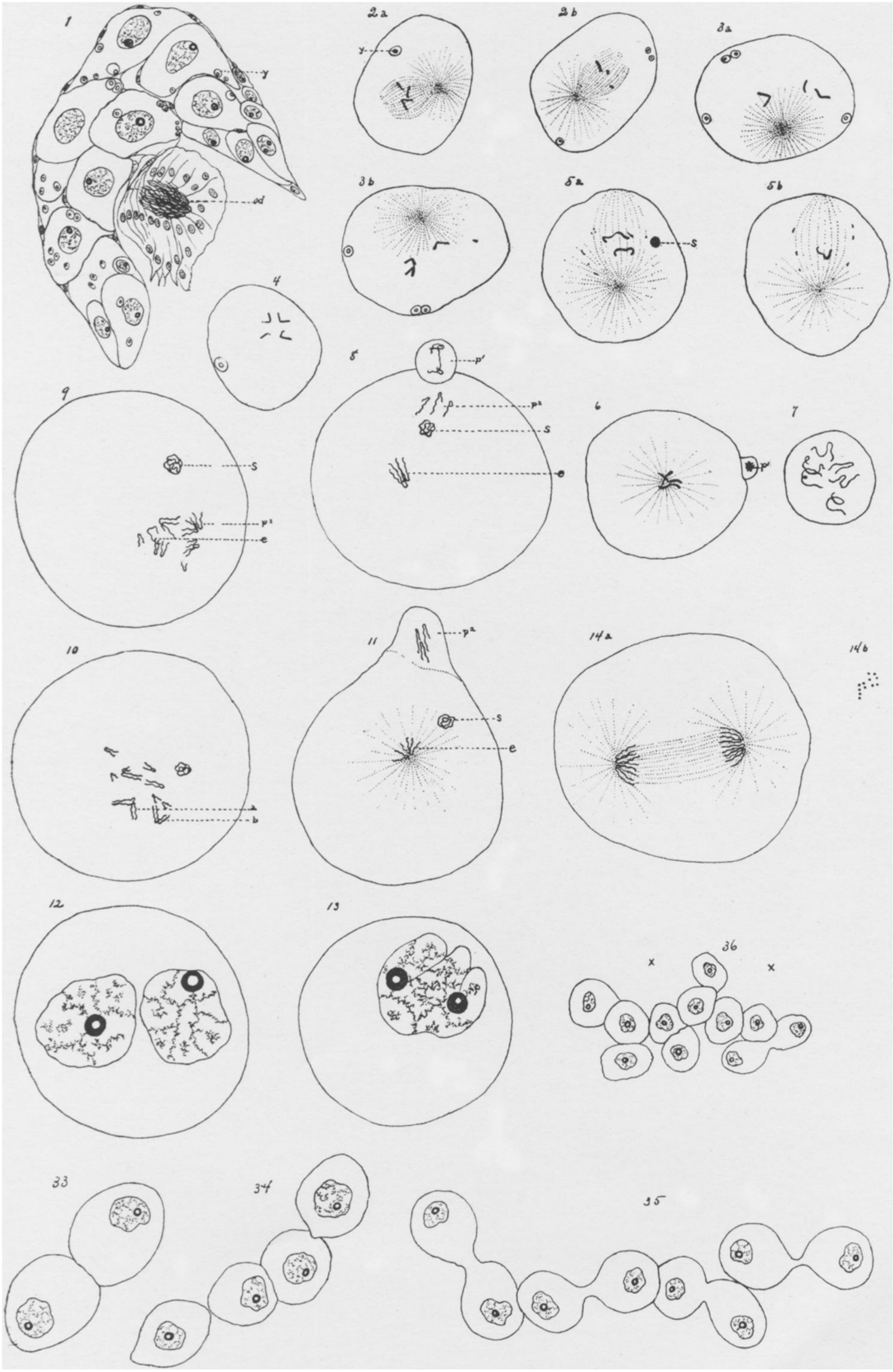
Fig. 53.—Cross-section of 12th day embryo ready to hatch, showing well-developed pharynx (p^2) and gut still filled with yolk-cells (y^2). B. and L. 1–C.

Fig. 54.—Another section from same embryo showing well-developed eyes and brain (b).

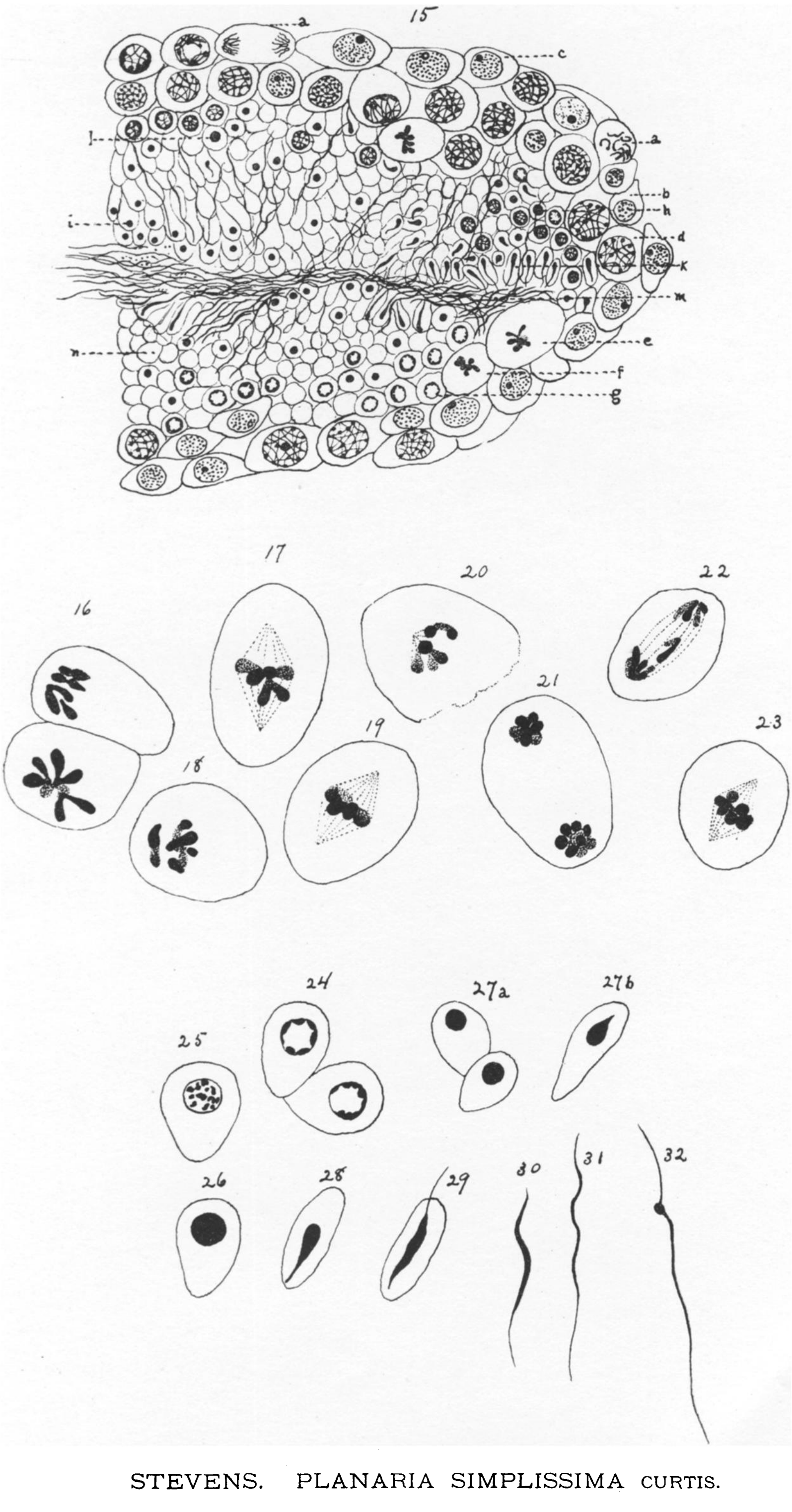
Figs. 55–56.—Endoderm-cells containing large masses of yolk (y^2), from same embryo as Fig. 53. B. and L. $\frac{1}{12}$–C.

Fig. 57.—Similar endoderm-cell from a young planarian one day old, yolk considerably disintegrated.

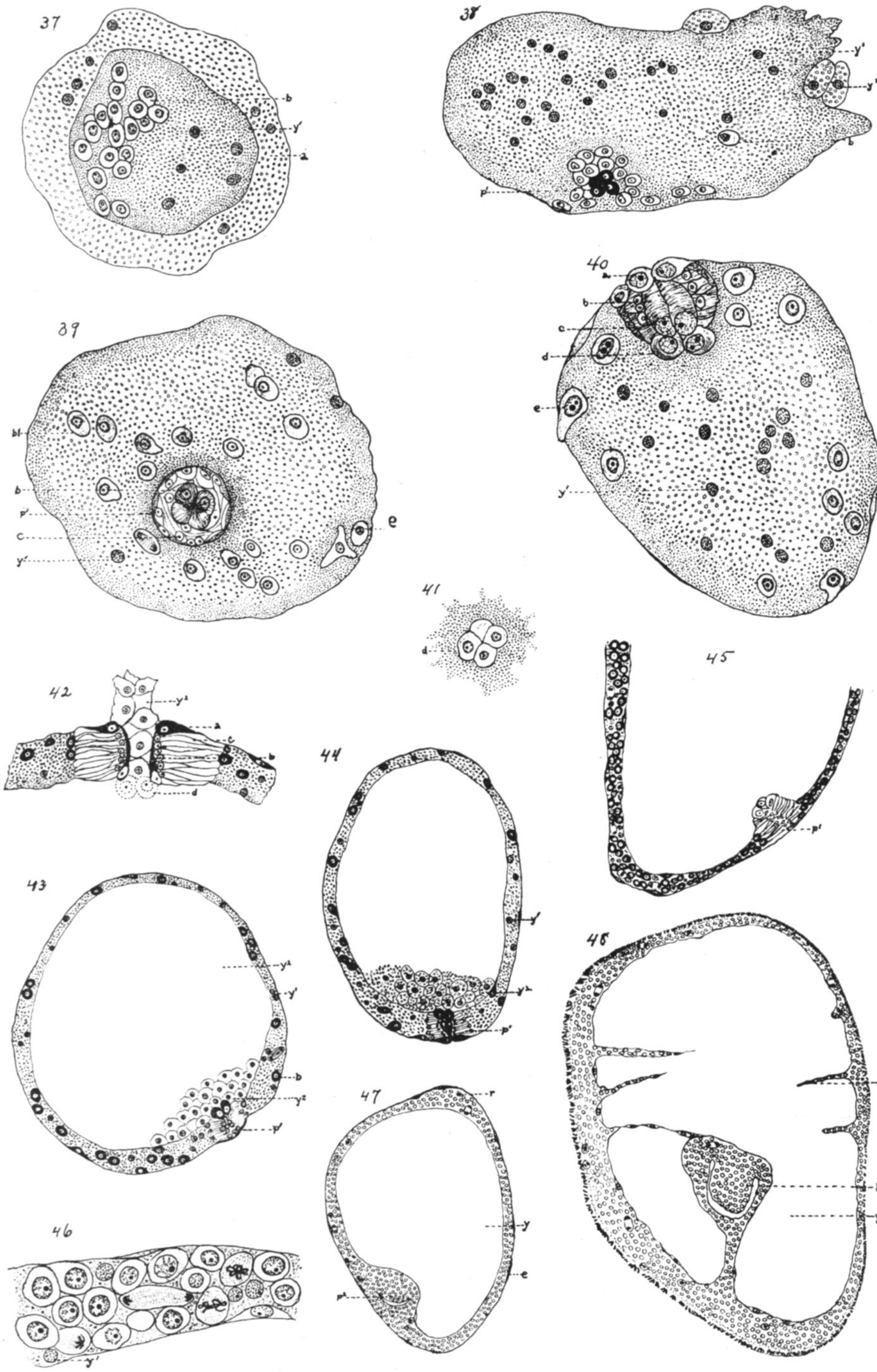
Fig. 58.—Longitudinal section of young planarian, one day old, tail-region shorter than in adult. (e = eye. b = brain. g = gut. p^2 = pharynx B. and L. 1–a.



STEVENS. PLANARIA SIMPLISSIMA CURTIS.



STEVENS. PLANARIA SIMPLISSIMA CURTIS.



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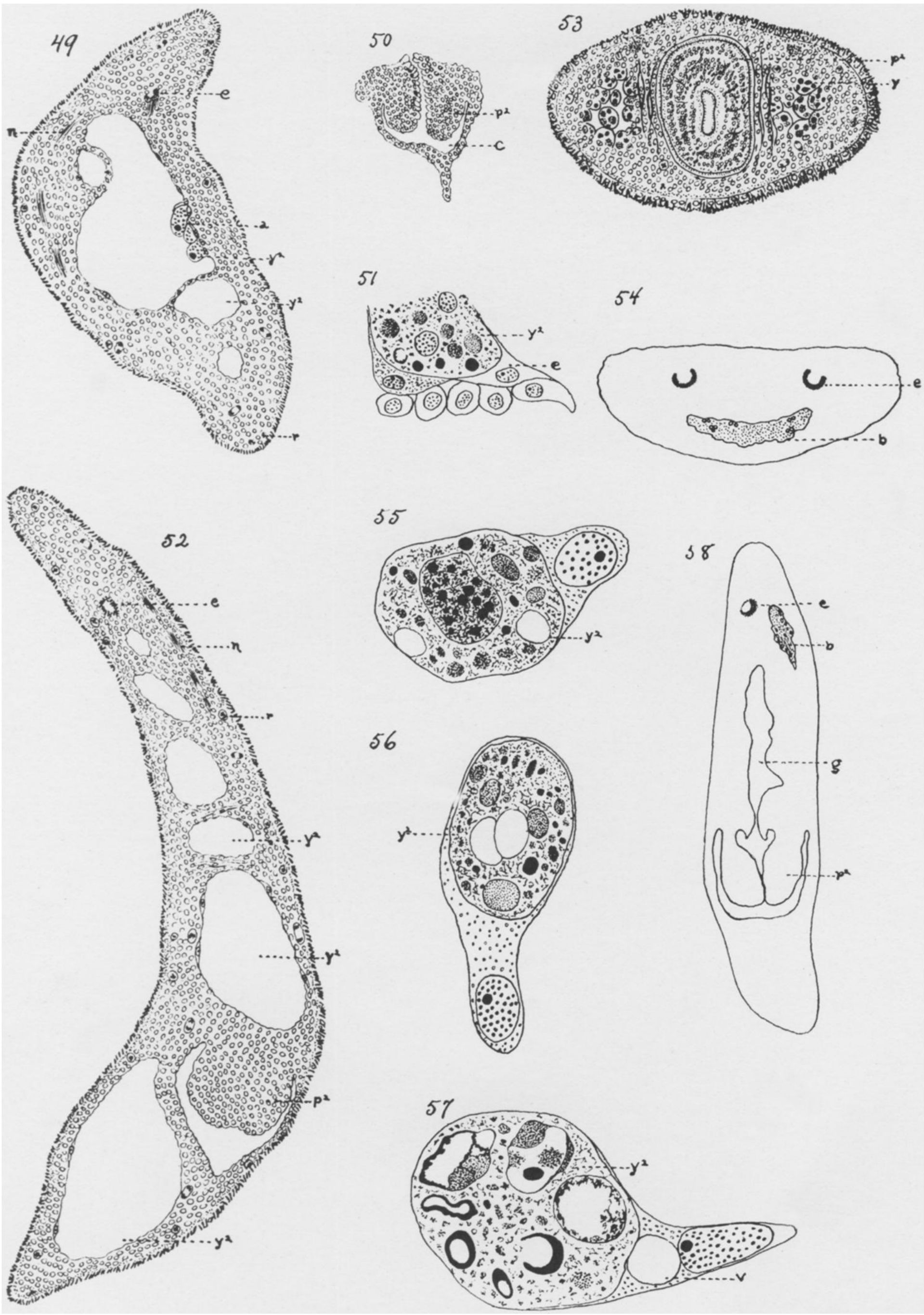

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